COMPARATIVE STUDY OF COMPRESSIVE STRENGTHS OF LATERITE-CEMENT AND SANDCRETE BLOCKS AS BUILDING MATERIALS

AGUWA J. I.
Department of Civil Engineering, Federal University of Technology, Minna, Nigeria
jiaguwa@yahoo.com
P.O. Box 3408 Garki, Abuja, Nigeria

ABSTRACT.

A comparative study of the compressive strengths of laterite-cement blocks and those of sandcrete was conducted with the purpose of cheaper building material sourcing in the prevailing escalating costs of housing. The study is also to establish the minimum cement content for desirable laterite-cement blocks. An A-2-6 according to AASHTO classification system was stabilized with 0-18% cement content by weight at 2% intervals to produce 200 laterite-cement blocks of size 100mm x 100mm x 100mm. In the same manner, size and mix ratio sandcrete blocks were also produced. All the 400 blocks were equally cured in the laboratory and subjected to compressive strength test at 7, 14, 21, and 28-days of ages in five replications for each cement mix ratio. Adequate strengths for load-bearing and non load-bearing walls were achieved with less cement content in laterite-cement blocks but not in sandcrete blocks.

Key Words: Cement; Compressive Strengths; Laterite-Cement blocks; Sandcrete blocks

INTRODUCTION

One of the basic needs for human being on earth is shelter and for this reason, the primitive man lived in a cave during the first stage of existence. Later the science of building huts for housing needs was learnt instead of living in the cave. Improvement on these huts continued with civilization and today the modern world has learnt to build nice and sophisticated bungalows and multi-storey buildings with adequate structural and aesthetic qualities. In Nigeria as well in most developing countries, sandcrete blocks are the most common and popular materials for walling units for domestic, industrial or commercial buildings. Traditionally, lateritic soils which are reddish brown in colour have been used as blocks for buildings without any cement content. Of recent, modern builders started introducing some percentage of cement to laterite for moulding their blocks, as a result of high cost of sandcrete blocks. A major advantage of the use of laterite instead of sand in moulding building blocks is the low cost, due to less quantity of cement required to produce blocks with adequate compressive strengths. This is in good agreement with earlier finding by

Metcalfe (1977) which reported that small amounts of cement inhibit the weakening effect of water and increase strength.

Laterite bricks were made by the Nigerian Building and Road Research Institute (NBRRI) and used for the construction of a bungalow, Madedor (1992). From the study, NBRRI proposed the following specifications as requirements for laterite bricks: bulk density of $1810kg/m^3$, water absorption of 12.5%, compressive strength of $1.65N/mm^2$ and durability of 6.9% with maximum cement content fixed at 5%.

Sandcrete blocks consist of Ordinary Portland Cement (OPC) and natural clean sand mixed with water in very carefully selected proportions. Sandcrete blocks are produced in two major forms as lightweight and dense blocks. Lightweight blocks are made with either lightweight aggregates or aerated concrete. Dense blocks are made with dense aggregates as specified in BS 882 (1983) which include natural sand and crushed rock. Blocks made with such aggregates have densities of 1920 to $2080kg/m^3$ and may be solid or hollow. Dense solid blocks made with natural sand were used in this research work. Cement as a binder is the most expensive input into the production of sandcrete blocks and this has necessitated producers to produce blocks with low cement content, in order to be affordable to people (Hombostel, 1991). In most cases, the producers of these weak sandcrete blocks and the users lack adequate engineering knowledge on the strength quality requirement of sandcrete blocks foe building (Aguwa, 1999).

This study aims at comparing the compressive strengths of laterite-cement blocks and sandcrete blocks at specified percentage of cement content as well as establishing the minimum cement content that can produce laterite-cement blocks with adequate compressive strength. Accordingly, the scope includes characterization of laterite and sand as well as the determination of the compressive strengths of laterite-cement and sandcrete blocks.

MATERIALS AND METHODS

Soil: The soil sample used was collected at a depth of 1.5m to 2.5m from an existing borrow pit behind Nigerian Television Authority station at Independence layout Enugu, Nigeria, (Latitude 6^o 26'N and Longitude 7^o 29'E), using the trial pit method of disturbed sampling. **Sand:** The sand collected from a river in Enugu, Nigeria and used as fine aggregate was clean, sharp, free from clay and organic matter.

Cement: The cement used was Ordinary Portland Cement (OPC) bought from a cement depot in Enugu and it conformed to BS 12 (1978).

Water: Tap water was used for the mixing and it was properly examined to ensure that it was clean, free from particles and good for drinking as specified in BS 3148 (1980).

Soil Index Properties

Index property tests on the laterite and sand for the purposes of characterization and classification, which include natural moisture content, particle size distribution, Atterberg limits, specific gravity, linear shrinkage and compaction tests on laterite-cement mixes were carried out in accordance with BS 1377 (1990).

Preparation of Specimens

The respective quantities of laterite, cement, as well as water required for the mix were proportioned and batched by weight at water/cement ratio of 0.5. In quality controlled mix such as this, measurement by weight was adopted, (Vazirani and Chandola, 1997). Manual mixing and moulding were used and proper mixing was achieved by turning the mixture from one side to the other for six times (Neville, 2000). Ten different mixes were prepared for laterite-cement and sandcrete using cement contents of 0, 2, 4, 6, 8, 10, 12, 14, 16 and 18% by weight of dry laterite and sand respectively. Two hundred (200) blocks of laterite-cement mixes of size 100mm x 100mm x 100mm were moulded by filling the mould in three layers and each layer was given 30 blows of compaction using a standard rammer of weight 2.5kg falling from a height of 30cm. To ensure even distribution of blows, approximately 100mm square sheet of plywood was placed on the mixture in the mould and compaction was done on it (Aguwa, 2008). The freshly moulded blocks were carefully extruded on a clean and flat surface and were cured under laboratory conditions. The same procedure was repeated for the production of two hundred blocks of sand-cement of the same size as the laterite-cement blocks.

Compressive Strength Test

An electrically operated Seidner compression machine was used for the crushing test on the blocks in accordance with Bs 1881 Part 116 (1983), at the curing ages of 7, 14, 21 and 28 days. Five blocks were crushed in each day for each mix of both materials respectively and the average compressive strength was measured. In crushing test, care was taken to ensure that the blocks were properly positioned and aligned with the axis of the thrust of the compression machine to ensure uniform loading on the blocks (Neville, 2000).

RESULTS AND DISCUSSION

Identification of Soil and Sand

The index properties of the sand and laterite used for the study are summarized in Table 1 while Figure 1 shows their particle size distribution. The sand was well graded and classified in zone 3 according to BS 882 (1983). The specific gravity of the sand is 2.62 and it is in good agreement with the recommendation of BS 1377 (1990) for clean quartz and flint sands. The laterite is brownish-red in colour with specific gravity of 2.64 and linear shrinkage of 10. The percentage of the soil passing sieve No 200 is 29.5 and the plasticity index is 20.5. The geotechnical index properties of the soil show that it is in the A-2-6 subgroup AASHTO (1986) soil classification system. An investigation into the geotechnical and engineering properties of sample as well as study of soil maps of Nigeria after Akintola (1982) showed that the sample collected belong to the group of ferruginous tropical soils derived from acid igneous and metamorphic rocks.

Table 1: Properties of the Natural Laterite and Sand

Characteristics	Laterite	Sand
Natural moisture content (%)	2.4	0.46
Percentage passing BS No 200 sieve (%)	29.5	0
Liquid Limit (%)	57	-
Plastic Limit (%)	36.5	-
Plasticity Index (%)	20.5	-
Linear shrinkage	10	-
AASHTO classification	A-2-6	
Maximum Dry Density (Kg/m3)	2028	-
Optimum Moisture content (%)	12.66	-
Specific Gravity	2.64	2.62
Condition of sample	Air-dried	Air-dried
Colour	Brownish-red	Brown

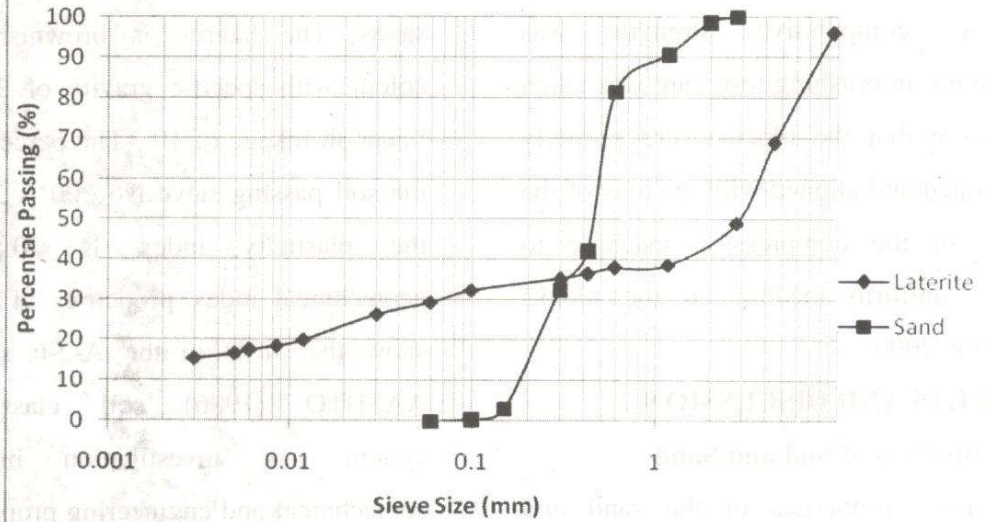

Figure 1: Particle Size Distribution for Laterite and Sand

Compaction Characteristics

The result of the compaction test on the Laterite is presented in Figure 2 indicating the maximum dry density (MDD) of 2028kg/m^3 and the optimum moisture content (OMC) of 12.66%. The variation of OMC with cement content at no compaction delay is shown in Figure 3. The increasing OMC with increasing cement content could be as a result of the extra water required for the hydration of cement. The effect of cement content on the MDD of laterite soil, at no compaction delay is also shown in Figure 5. There was increase in MDD with increase in cement content and this is consistent with the results reported by Agbede and Manasseh (2008). The increase in MDD with increasing cement content could be attributed to voids of the natural laterite being filled with cement with a higher specific gravity of 3.15. When the laterite soil with specific gravity of 2.64 was mixed with cement that has specific gravity of 3.15, the tendency was for the soil-cement mixture to increase in dry density. The increase in both OMC and MDD with increase in cement content was however slight as can be seen from the Figures 3 and 4.

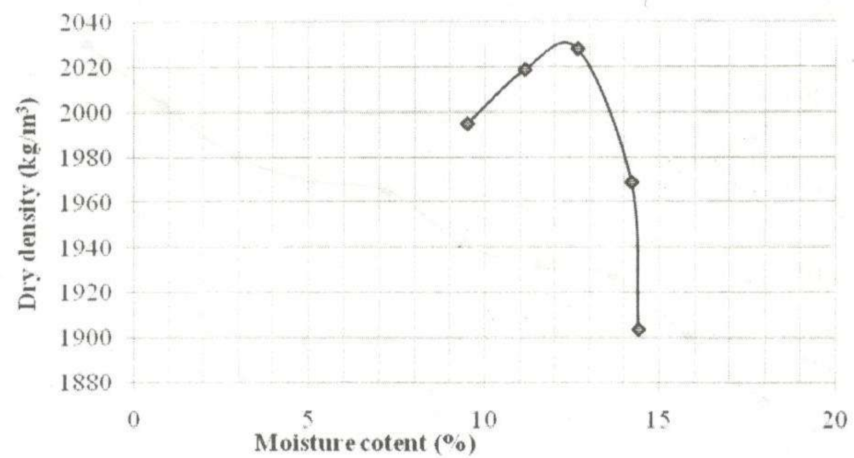

Figure 2: Dry density-Moisture cotent Relationship for

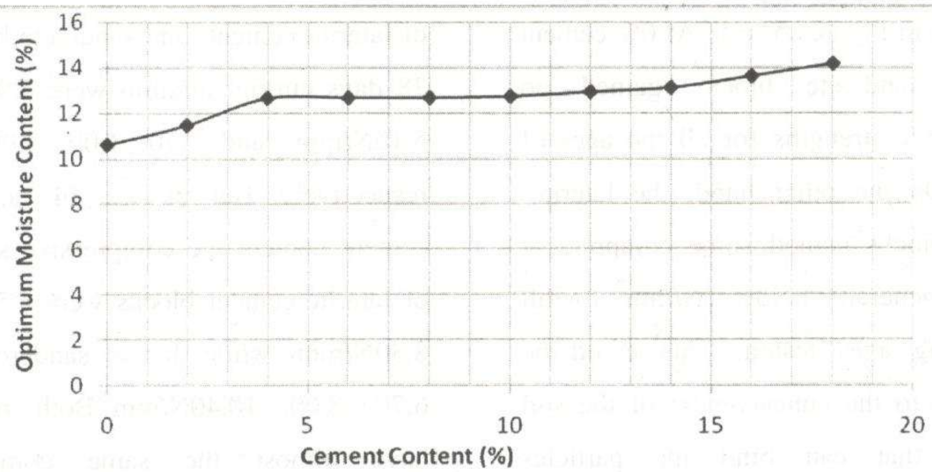

Fig 3: OMC-Cement Content Relationship for Laterite-Cement Mixes

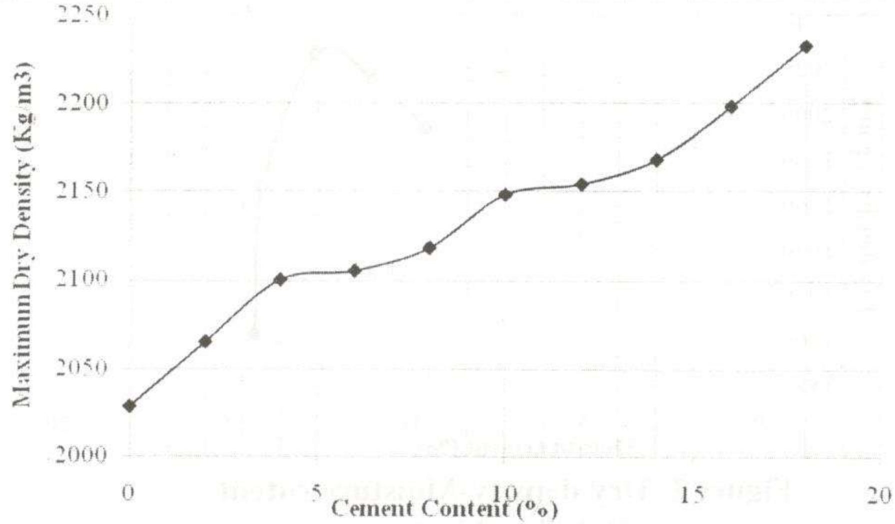

Fig 4: MDD-Cement Content Relationship for Laterite-Cement Mixes

Compressive Strength

The result of compressive strengths test for laterite-cement and sandcrete blocks at various cement contents are presented in Figures 5 to 8. At 0% cement content, sandcrete blocks gained no compressive strengths for all the ages of curing. On the other hand, the laterite-cement blocks gained some compressive strength generally below 1N/mm^2 for all the curing ages tested. This could be attributed to the cohesiveness of the soil material that can bind the particles together. It is an indication that only laterite could be used in certain areas of building requiring no load-bearing. Laterite-cement blocks consistently gained greater compressive strength values up to 10% cement content while sandcrete blocks recorded greater compressive strength values for cement contents above 10% for all the curing ages of 7, 14, 21 and 28-days. For example, at 4, 6 and 8% cement content, the compressive strengths of laterite-cement and sandcrete blocks at 28 days curing duration were 1.90, 3.50, 5.10N/mm^2 and 0.70, 1.00, 3.90N/mm^2 respectively But at 12, 14, and 16% cement content the compressive strengths of laterite-cement blocks were 6.50, 7.15, 8.30N/mm^2 while that of sandcrete were 6.70, 8.00, 10.40N/mm^2.Both materials have almost the same compressive strengths at 10% cement content for curing ages of 14, 21 and 28-days. Adequate compressive strength of 3.5N/mm^2 for buildings was achieved with cement content of 6% in laterite-cement mix but not in sandcrete mix, implying that laterite-cement mix is a more economical building material than sandcrete, because the later requires more cement to achieve

the suitable strength. The lowest crushing strength of individual load bearing blocks shall not be less than 2.5N/mm^2 for machine compaction and 2.0N/mm^{2}for hand compaction as recommended by NIS 87 (2004). This result is in good agreement with the finding of Alutu and Oghenejobo (2006) who reported that for 7% cement content and13.76N/mm^{2}compactive pressure, cement stabilized laterite blocks with compressive strength of at least 2.0N/mm^2 at 28 days could be produced. The compressive strengths increased with increase in cement content within the range of cement content studied for both laterite-cement and sandcrete blocks. This trend was noted by Metcalfe (1977) that in general, the strength increases is in direct proportion to cement content, but at different rates for different soils. However, higher cement contents result in prohibitive cost of blocks which places the sand-cement blocks at a disadvantage.

The laterite-cement blocks consistently showed a definite pyramidal pattern type of failure. The conical shape was found to be the same as that of concrete cubes subjected to compression test (Neville, 2000). This is an indication that buildings constructed with laterite-cement blocks will likely withstand considerable deformation before total failure. In contrast to the laterite-cement blocks, the sandcrete blocks consistently showed fragments at failure which indicated that they cannot withstand considerable deformation before total failure.

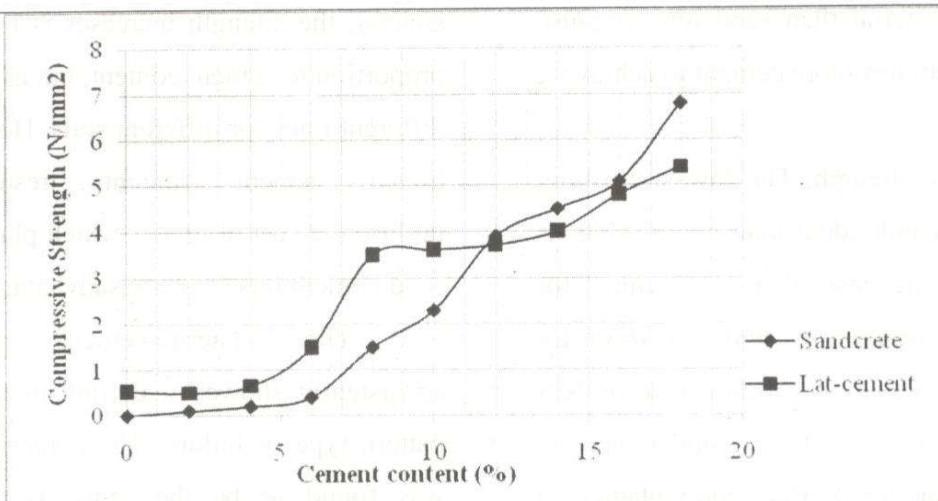

Figure 5: Compressive Strengths at 7-days for Sandcrete and Laterite-cement blocks

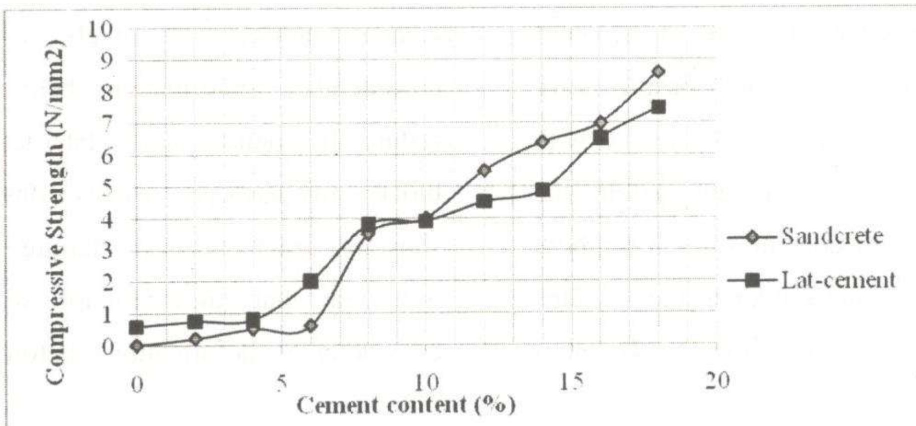

Figure 6: Compressive Strengths at 14-days for Sandcrete and Laterite-cement blocks

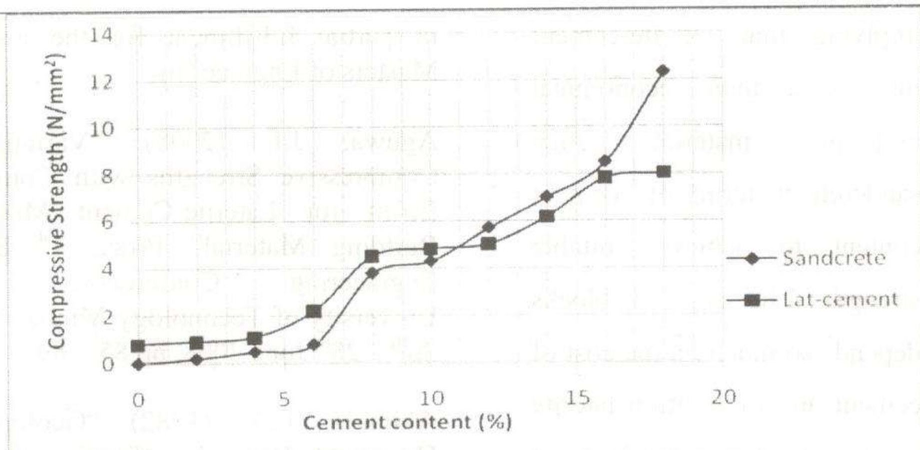

Figure 7: Compressive Strengths at 21-days for Sandcrete and Laterite-cement blocks

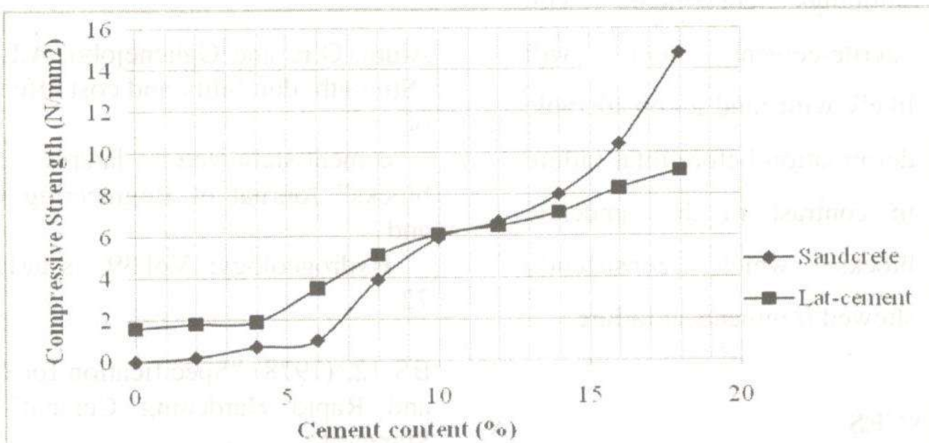

Figure 8: Compressive Strengths at 28-days for Sandcrete and Laterite-cement blocks

CONCLUSION

The over all conclusions emerging from the present study are that:

1. The compressive strengths for both laterite-cement and sandcrete blocks increased with higher cement contents within the range of cement content studied but generally higher for laterite-cement mixes than those of sandcrete mixes for cement contents below 10% while that of sandcrete mixes were higher at cement contents above 10% for all curing durations.
2. Adequate compressive strengths for buildings were achieved with cement content of 6% in laterite-cement mix but not in sandcrete mix,

implying that laterite-cement mix is a more economical building material than sandcrete in terms of cement content to achieve suitable strength. The cost of blocks depends so much on the cost of cement and in addition laterite is cheaper than sand in most rural areas of the tropics where they occur in vast quantities.

3. Buildings constructed with laterite-cement blocks will likely withstand a considerable deformation before total failure in contrast to the sandcrete blocks which consistently showed fragments at failure.

REFERENCES

AASHTO (1986) "Standard Specifications for Transportation Materials and Method of Testing and Sampling" American Association of State Highway and Transportation Officials, Washington D.C., U.S.A

Agbede, I.O. and Manasseh, J. (2008) "Use of Cement-Sand Admixture in Laterite Bricks Production for Low Cost Housing" Leonardo Electronic Journal of Prctices and Technologies, ISSN 1583-1078, Issue 12, pp.163-174.

Aguwa, J.I. (1999) "Sandcrete Block Mix." Thesis presented and submitted in Civil Engineering Department, Federal University of Technology Minna, Nigeria, in partial fulfillment for the award of Masters of Engineering

Aguwa, J.I. (2008) "Variation of Compressive Strengths with Compactive Effort for Laterite-Cement Mix as a Building Material" Proc., 1st Biennial Engineering Conference, Federal University of Technology Minna, Nigeria, 26th – 28th June 2008, pp.85 – 89.

Akintola, F.A. (1982) "Geology and Geomorphology, In Nigeria in Maps" edited by K.M Barbours, Hodder and Stoughton, London

Alutu, O.E. and Oghenejobo, A.E. (2006) "Strength, durability and cost effectiveness of cement-stabilized laterite hollow blocks" Journal of Engineering Geology and Hydrogeology; Vol.39, issue1, pp.65-72

BS 12: (1978) "Specification for Ordinary and Rapid Hardening Cement" British Standard Institution, 2 Park Street, London, WIA 2BS

BS 3148: (1980) "Tests for water for making concrete." British Standard Institution, 2 Park Street, London, WIA 2BS

BS 882 (1983) "Specification for Aggregates from Natural Sources for Concrete" British Standard Institution, 2 Park Street, London, WIA 2BS

BS 1881 Part 116 Methods for Determining Compressive Strengths of Concrete Cubes

British Standard Institution, 2 park Street, London, 1983

British Standard BS 1377: (1990) "Methods of test for Soils for civil engineering purposes."

British Standard Institution, 2 Park Street, London, WIA 2BS

Hombostel, C. (1991) "Construction Materials: types, uses and application." John Wiley & Sons Inc., U.S.A, p.271

Madedor, A.O. (1992) "The impact of building materials research on low cost housing development in Nigeria" Engineering Focus April–June, publication of the Nigerian Society of Engineers, Vol. 4, No 2, pp.37-41

Metcalfe, J.B (1977) "A laboratory investigation of strength/age relations of five soils stabilized with white hydrated lime and Ordinary Portland Cement", RN/3435/JBM, DSIR, RRI.

Neville, A.M. (2000) "Properties of Concrete" 4th Ed. Pearson Education Asia Ltd, Kuala Lumpur, Malaysia

NIS 87: (2004) "Standard for Sandcrete Blocks" Nigerian Industrial Standard Approved by Standard Organization of Nigeria (SON)

Vazirani, V.N. and Chandola, S.P. (1997) "Concise Handbook of Civil Engineering." Schand & Company Ltd, 7361 Ramnagar, New Delhi-110055, p.1135